conference of the Museums Association and now published in the *Museums Journal* (October 1922), supports Lord Sudeley in his demand for a Royal Commission. Mr. Bailey, who, as sometime secretary for the Circulation Collections at the Victoria and Albert Museum, knows the provincial museums on their art side better than most men, has no difficulty in making out a case for reform. He is particularly strong on the unjust and unequal incidence of the aid which, though diminished, is still given to local museums by the State through some of the national museums. The officers of the Government establishments, always so willing to help, would doubtless be glad to see the way made clearer for them. Mr. Bailey's criticism on these and other weaknesses is destructive. There are schemes enough in the air, and he does not add to them. He asks, and he has induced the Museums Association to ask, for a Royal Commission, so that any recommendations may ultimately be based on the fullest possible knowledge. We agree fully that there is need for reorganisation, and we believe that a large amount of reform might be effected without material increase of expenditure; indeed, some of the obviously desirable reforms would tend to economy. But, while we sympathise with the request of the museum folk for a Royal Commission, we fear that they are not now very likely to get it. The subject, indeed, deserves serious discussion and it would be well to have various proposals compared and investigated, so that when changes are effected they may be guided by a definite policy. Some inquiry, less expensive than that by a Royal Commission, might elicit the information and put forward an accepted ideal towards which all could work.

Any such inquiry should, however, approach the subject on the broadest possible lines. The resolution passed by the Museums Association asks for a "report upon the work of the museums of the United Kingdom in relation to industries and general culture." The importance of museums on the industrial side has been recognised by the Federation of British Industries in a recent report. "General culture" is an expression that may include much or little; presumably it is intended to comprise scholastic education. But there are the numerous activities of museums that aid the extension and application of knowledge in ways that do not seem to fall under these heads. Whatever their subject-matter, and whatever their immediate and distinctive aim, all museums work by the same method —the accumulation, preservation, and demonstration of concrete objects; they are guided by the same broad principles, and need the same kind of assistance. Though they may be co-ordinated with other social activities—industrial, educational, artistic, and the rest —they must not be confused with them. Any inquiry therefore must deal with museums as such, in relation to all their multifarious aims and activities, and must seek to bring all into one harmonious collaboration for the common weal.

Meteorological Theory in Practice.

(1) *Weather Prediction by Numerical Process.* By Lewis F. Richardson. Pp. xii+236. (Cambridge: At the University Press, 1922.) 30*s*. net.

(2) *Forms whereon to Write the Numerical Calculations described in "Weather Prediction by Numerical Process."* By Lewis F. Richardson. 23 forms. (Cambridge: At the University Press, 1922.) 2*s*.

IN the book under notice Mr. L. F. Richardson presents to us a *magnum opus* on weather prediction. The numerical manipulation of the dynamics and physics of the atmosphere is its mainspring; but there is a fine display of other works of an intricate character. Its avowed object is nothing less than the calculation of future events in weather; and this by inserting numerical values in seven fundamental formulæ, which, taken together, embody the essential analysis of the sequence of weather. Three of the equations express the time-rate of change of the easterly, northerly, and vertical components of the momentum of the air; other three express the time-rate of change of its density, water-content, and heat-content respectively. The seventh is the characteristic gas-equation for air; it contains no differentials.

The whole history of the atmosphere is to be unrolled on computing by finite differences the changes in the elements in terms of the changes of four independent variables representing space of three dimensions and time. The formulæ all relate to an individual sample of air in a column at a single point; but the calculation has to say what will happen to the whole mass in the neighbourhood of every specified locality within the region of observation. Hence representative points are chosen for which the changes of the variables are to be computed at a sufficient number of levels to give a working idea of the changes in the weather. The points are grouped in a lattice or chess-board with each square 200 kilometres long, 3° of latitude broad, and 2 decibars of pressure thick: the whole atmosphere is thus treated as made up of 16,000 slab-units each weighing about half a billion tons. What we call weather is represented by the physical changes in the slabs. The standard time-interval over which uniformity of change is preserved is six hours. Observations of pressure and temperature are taken for the centres of the "red" slabs of the chequer, which lie in columns of five deep; observations of momentum at the centres of the "white." The changes in any one slab are computed with the aid of the known conditions of the surrounding slabs: hence the calculation for any arbitrary area is limited to the interior slabs, and the area amenable for computation diminishes with each step of the process. There is a great amount of original and ingenious scientific speculation and discussion in the description of the process.

Nearly a hundred separate algebraical symbols are employed. The author sketches a fancy picture of the process of computation going on for the weather of the whole world in a great theatre or forecast-factory in the form of a hollow globe. A spherical orchestra of computers calculates the future weather from the information supplied by 2000 stations under the direction of a conductor at the centre of the globe. In order to keep pace with the weather the orchestra would consist of 64,000 performers on the slide-rule or calculating machine; and even then, with a space unit of 200 kilometres, phenomena on the small scale, such as tornadoes or local thunderstorms, might be missed. Part of the appeal of the book is for a distribution of stations to be arranged so as to give the process of calculation a better chance than the existing distribution in Europe affords.

There are twelve chapters of very unequal length. Chapter I. is a brief summary of the contents of the book; Chapter II. is a simplified example of the method of calculation by finite differences which is to be used. This preliminary canter shows incidentally that a distribution of pressure according to an assumed geometrical law, and a universal geostrophic wind corresponding therewith, lead to the conclusion that a vast system of high pressure over the Eurasian continent, covering one half of the Northern hemisphere east of the meridian of Greenwich, would result in an increase of pressure over England, which lies on the margin. This result is regarded as axiomatically contrary to fact, because "cyclones" are known to pass eastward. We are therefore invited to conclude in passing that the geostrophic idea is inadequate. That is certainly a possibility but not the only one. Since the geostrophic idea is based upon our experience of natural distributions of pressure we might with equal justice conclude that the assumed geometrical distribution is a non-natural one. Or better still, we might say that Mr. Richardson's preliminary canter has given a rigorous dynamical explanation of what is meant by "an anticyclone resisting the advance of a cyclone," a very common statement of meteorological phenomena. The reviewer preserves in memory two natural pictures of an Atlantic cyclone kept at bay by a current from the east and presenting an appearance grotesquely like a revolving ball balanced on a water-jet. A notable feature of our northern winter is a vast anticyclone over Asia which dominates the northern half of the eastern hemisphere like Mr. Richardson's pattern, although the distribution over the other quadrants of the globe is not at all like the pattern. As a matter of experience the anticyclone does frequently spread from the east over England. Our weather might not inaptly be described as a conflict between the effect which Mr. Richardson repudiates as contrary to experience and the eastward travel of cyclones which he regards as axiomatic. Not infrequently, the result of the conflict is that the cyclones, instead of going eastward over us, are headed off to the north along the Norwegian Sea—"which nobody can deny."

In view of our inadequate knowledge of the structure and circulation of the atmosphere caution in drawing conclusions is always desirable, and in this case specially so in the interests of justice, because the alleged failure of the geostrophic principle to anticipate the changes at the surface in Chapter II. reappears in Chapter VI. as the record of a previous conviction, and gets the prisoner another sentence for what is perhaps not his fault. Mathematicians in dealing with the elusive atmosphere are not infrequently inspired by Jabberwocky,

> One two, one two, and through and through,
> The vorpal blade goes snickersnack;

but they ought to make sure that they get the right Jabberwock by the neck before "galumphing back" with his head.

Chapter III. reinforced by Chapter VII. explains a suitable organisation of what are called co-ordinate differences, the principles of the chess-board or lattice. Chapter IV., a very important one, occupies more than one-third of the whole book. It is devoted to the fundamental equations and the information which is necessary in order to assign numerical values for the variables. It takes the form of about thirty short essays on great subjects, such as the effects of eddy-motion, radiation, conduction of various kinds, the flow of heat to the air from the sea, or from the ground, or from vegetation, the smoothing of observations, and many others. Chapter V. deals with the evaluation of vertical velocity, a very vital subject. Chapter VI. deals with the special conditions for the stratosphere and its equations. Chapter VIII. reviews the numerical operations to be performed and gives the final preparation for Chapter IX., which provides a "full-dress rehearsal" of the process of computation. By its aid the changes of pressure and temperature for a point near Munich and the changes of momentum at a point between Munich and Hamburg are calculated for the interval of six hours centred at 1910 May 20d. 7h. G.M.T. That day was chosen for displaying the method because a set of data for the surface and upper air was available in the publications of the Geophysical Institute of Leipzig issued by Professor V. Bjerknes. Although not quite adequate for the purpose it is an unusually full set.

The calculation occupied "the best part of six weeks" in a rest-billet in France. It included, however, the preparation of the forms which are now issued in blank for the use of others who may be attracted by the prospect of submitting the course of Nature to the process of numerical calculation. Every assistance is given by the forms and by suggestions for improving the accuracy, smoothing the data, and many other technical points of manipulation.

The trial specimen is not such a good example of the art of forecasting that it tempts the reader forthwith to become one of the great orchestra. The change of pressure at the surface works out at 145 millibars in six hours. Our barometers allow for a range of 100 millibars at most; and, as a matter of observation, the change in the region in question was less than a millibar: the wildest guess, therefore, at the change in this particular element would not have been wider of the mark than the laborious calculation of six weeks. Nor is that all. Many of the chapters end in parenthetic expressions of regret or of suggestions for improvement. There are also many supplementary paragraphs which indicate that when the author comes to make another edition, as he or some one else undoubtedly will, he will write somewhat differently. And the reader will not be sorry, for in many ways the book makes hard reading. It is full of mathematical reasoning, a good deal of which is conducted "by reference." The reader who wishes to follow it must have a very handsome library and a few step-ladders which Mr. Richardson does not provide.

A reviewer with less than the ordinary sufferance of his tribe might easily murmur: forecasting by numerical process seems so arduous and so disappointing in the first attempts that the result is a sense of warning rather than attraction. He might also wonder for whom the author is writing, and regard the book as a soliloquy on the scientific stage. The scenes are too mathematical for the ordinary meteorologist to take part in and too meteorological for the ordinary mathematician. But such complaint would be as misleading as the computed forecast. On the road to forecasting by numerical process nearly every physical and dynamical process of the atmosphere has to be scrutinised and evaluated; the loss of view into the future from the first summit is compensated many times by the insight which one gets into the working of Nature on the way. For example, the author draws from the miss of his forecast the conclusion that the observations of velocity used are a real source of error. Whether that conclusion is true or not, its further consideration is of the greatest importance in view of the multiplicity of observations of winds in the upper air and of the difficulties which their interpretation presents.

The essential obstacle in the way of bringing the facts of weather into mutual co-ordination by recognised methods of dynamics and physics is that there are so many of them, so many elements, so many variables, so many causes of perturbation. Some meteorologists look for a general solution of the problem in the discovery of new physical laws, at present unthought of, that will make things clear. Yet, even when we revel in the proud consciousness of being familiar with all the ultimate dynamical and physical laws to which the atmosphere is subject, we may yet fail in an endeavour to relate the conditions of the moment to those of the past or to anticipate the future from the present by lack of method in the arrangement of the facts.

When we look back at the triumphs of calculation of the historic past we find always that the skilful calculator has substituted an ideal, upon which it is possible to operate, for the intractable reality. The late Lord Rayleigh made the general position clear in his first volume on "Sound," where he pointed out that in order to study sound as vibration we imagine the sounding body to be completely isolated, though, if it were so, there would be no sound. Mr. Richardson in his preface properly cites the Nautical Almanac as an alluring example of forecasting by numerical process. We are reminded of Plato's maxim, "We shall pursue astronomy with the help of problems just as we pursue geometry, but we shall let the heavenly bodies alone if it be our desire to become really acquainted with astronomy." Perhaps astronomers have been disposed to press this maxim to the extreme, yet we must admit that the Nautical Almanac owes much to the ellipse in substitution for the actual orbits of the heavenly bodies. It would perhaps be difficult to imagine anything more unreal than the latest ideal of the atom.

Hence we might argue that the first step in meteorological theory should be to group the facts in such a way as to replace the reality by a reasonable and workable ideal. That view underlies the work of Hildebrandsson and Teisserenc de Bort in "Les Bases de la météorologie dynamique," in which they endeavoured to present the ascertained facts in a collected form in order to lead up to a working ideal, believing that premature analysis had always proved unfortunate. For two generations now the general ideal of our atmosphere has been that of a succession of travelling cyclonic vortices and anticyclonic areas. Hildebrandsson and Teisserenc de Bort provided a normal permanent circumpolar vortex in which travelling cyclones might be formed. But the ideal presented is still inexcusably vague and undeveloped: there is much to be done before we can say even what we ought to look for in a map if we wish to identify a vortex travelling under the normal conditions of the atmosphere and we are not yet ready to do justice to that ideal.

Prof. Bjerknes on the other hand has set out to prove that our maps can be simulated or stimulated by wave-motion on either side of a surface of discontinuity which separates equatorial air from polar air. Here we may note a tendency to follow another Greek maxim, this time of Aristotle, "for those things which escape the direct appreciation of our senses, we consider we have demonstrated them in a manner satisfactory to our reason when we have succeeded in making it clear that they are possible."

In "Weather Prediction by Numerical Process" Mr. Richardson follows a line of thought which differs widely from either of these. His main simplifications are to divide the atmosphere into his 16,000 slabs and to ignore perturbations which are on a smaller scale than a hundred miles. The rest is rigorous. The principle which lies at the bottom of his treatment of the subject is that the known laws of dynamics and physics as applied to the changes which take place are inexorable and are sufficient. The future can therefore be derived from the present by their application. They can be applied by the step by step method of finite differences with sufficient accuracy to obtain the general consequences of the present conditions. The illustration of the process is a most valuable contribution to meteorology and indicates a wholesome course of practical physics and dynamics of the atmosphere which may prove the basis of future teaching. Thus it will not only provide an acid test of meteorological theory but also be a valuable guide to the organisation of new meteorological observations.

Finally, perhaps the most important aspect of this contribution to meteorological literature is that a rigorous differential equation is not necessarily useless because it cannot be integrated algebraically. It opens the way to useful exercises less stupendous than calculating the weather, and indeed, whenever meteorology comes to be taught and learned, the book will be a rich quarry for the teacher and examiner.

Napier Shaw.

Parker and Haswell's "Zoology."

A Text-book of Zoology. By the late Prof. T. J. Parker and Prof. W. A. Haswell. In Two Volumes. Third Edition. Vol. I., pp. xl+816. Vol. II., pp. xx +714. (London: Macmillan and Co., Ltd., 1921.) 50*s*. net.

WHEN a demand arises for a new edition of a general text-book on some branch of science, the problem before the editor is to decide whether the new wine of recent discovery will go with safety into the old bottle. The solution depends largely upon the adaptability of the original scheme. When the treatment has been dominated by one aspect of the subject-matter, or when the science has entered on a new transitional phase of discovery involving new points of view, the new wine requires a new bottle.

Parker and Haswell's "Text-book of Zoology" illustrates this difficulty. Its outlook on the great and varied theme of animal life is fixed on the static anatomical aspect, on the intensive analysis of individual structure, and on the grouping of animals in classes according to structure. So fascinating and so adaptable to educational discipline is this pursuit that the anatomical aspect is only too apt to dominate other and equally important methods and aspects of animal study. It is against this over-emphasis of descriptive anatomical detail that teachers of zoology have been protesting for many years, with the result that in practice there is a more balanced consideration of the dynamical as opposed to the statical aspect of zoology.

In this respect the new "Parker and Haswell" is disappointing. The rigidity of its structure has prevented its editor from adapting the text of these two volumes to modern requirements, or from embodying more than a very small amount of the new matter and none of the new points of view that zoologists have discovered in the last twenty years. The chief revision is limited to three groups of Invertebrates—the Nematodes, Polyzoa, and Annelids—while the whole of the second volume—the Vertebrates and the philosophy of zoology—has, so far as can be readily ascertained, undergone little change.

Ungrateful as is the task of adverse criticism, it must be acknowledged that this revision has not gone far enough. In contrast to the vigorous handling of the Platyelmia and Annelids, the loose treatment of the Nematoda is very pronounced. The account of the life-history of the common Ascaris is both wrong and misleading, and the description and figure of the hook-worm are most inadequate. In fact, in regard to parasitology generally, one has but to compare the little book recently published by M. Caullery and